A Flow Mobility Management Architecture Based on Proxy Mobile IPv6 for Vehicular Networks

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***Abstract*—Vehicular network applications may be benefited by the use of simultaneous network interfaces to maximize throughput and reducing latency. In order to take advantage of all radio interfaces of the vehicle and to provide a good quality of service for vehicular applications, we have developed an architecture that performs the management of the flow mobility based on some classes of application for vehicle network. Our goal is to minimize the time of handover between the rings of flows in order to meet the minimum requirements of vehicular applications, as well as to maximize the throughput. Simulations have been conducted to analyze the performance of the proposed architecture by comparing it to other previously devised architectures. As a result, the proposed architecture presented a low delivery time of messages, packets with lower loss and lower delay.**

I. Introduction

In the last decade, the use of mobile devices, ad hoc communication and ubiquitous computing have enabled several classes of applications and services through the change of information anywhere and at any time. The use of mobile communication in vehicles is expected to becomes a reality in a few years as automotive industry, governments, and universities around the world are applying resources to create an efficient and safe transport system [1]–[3]. Vehicular ad hoc networks, or simply vehicular networks, are a special type of ad hoc mobile networks where vehicles are equipped with a wireless interface and processing and sensing devices. These vehicles create a mobile network during its journey through the streets [4]–[6].

Applications in vehicular networks can be divided into three classes [2]: entertainment, safety, and driver assistance. The entertainment applications support the access to internet, advertisements, content sharing, chats, and others. Applications related to safety aims to provide the driver with information related to the traffic of cars in its path, such as traffic jams, road conditions, and accidents. The purpose of these applications is to forward information to the driver to decide, in due time, the best solution for safe transport. Driver-support applications supply information dynamically, considering all the support solutions and applications for Intelligent Transport Systems (ITS) [2], [7].

In addition to communication between vehicles, information and communication technologies can be used to support the various applications in Intelligent Transport Systems. By using different communication technologies, vehicles, using different network interfaces, can forward packets to different networks in order not to lose the data connection to support a given application. The network mobility management is performed through the handover component. A well managed handover can allow a mobile device to maintain its active connection traversing different communication networks.

The handover takes place when a device connected to another device/access point moves away from its coverage area, entering the coverage area of another device/access point [4]. In this context, a mechanism that performs the transfer of connections is required, so the current connection does not undergo any interruption. The handover can be classified in horizontal and vertical. The horizontal handover consists of the connection transfer between devices through the same networking technology. The vertical handover on the other hand involves connection transfer between devices through different network technologies, such as in environments presenting heterogeneous networks. Besides these aspects, issues such as security, bandwidth, delay, and data flow should be taken into consideration when performing the handover.

Due to the many complex aspects involved with a vertical handover, a communication architecture is required to manage different connections considering different network technologies. The aim of this paper is to propose a common communication architecture to perform the handover efficiently. A study on the different classes of applications has been conducted by setting minimum requirements for packet loss, throughput, and delay in vehicular communications. The flow manager examines the status of active connections that can be used to perform handover with minimum application requirements. The vertical handover is done considering WiFi, LTE (Long Term Evolution and 802.11p) as the communication technologies. In this work, the proposed architecture was compared with previous solutions, considering the following network metrics: communication delay, time to perform the handover, number of control messages, and data packet loss. The results show that the proposed architecture is able to perform vertical handover more efficiently when compared with the other solutions.

The remaining of the paper is organized as follows. Section II describes the related works. Section III introduces the architecture for performing the vertical handover in vehicular networks. Section IV presents and discuses the simulation results. Finally, Section V concludes the paper and draw director for future work.

II. Related Works

Some studies has been already conducted in order to enhance the performance of handover. The following mechanisms have been developed aiming at allowing simultaneous use of multiple interfaces for mobility vehicles to ensure continuous data flow.

The authors in [8] proposed a handover mechanism for streaming over IP. The mechanism is optimized for packet traffic and is based on network-based mobility management. The proposed mechanism uses the fast handover protocol PMIPv6 (FPMIPv6). Since this protocol does not support flow management, the authors defined new mobility headers; the handover initiation for flow mobility (HIF) sends information of a MAG (Mobile Access Gateway) to the other of the mobile node. Another message that has been incorporated by the authors acknowledge the handover is flow mobility (HAF), which is an extension of the handover acknowledgement message (HACK) responsible for sending commands to MAG. The HACK message is defined in the FPMIPv6 protocol. These headers are an extension of the Handover Initiate (HI), which is responsible for the mobility management in the FPMIPv6 protocol. This extension was carried out aiming to obtain improved efficiency in the flow of carrier mobility in FPMIPv6. In addition, a new mobility option is set for the transmission of information of the communication interface, called option *interface-status-and-action* (ISA), which indicates the mobile node status, as well as the expected action the mobile node's network interface.

Makaya et. al. [9] devised a new mechanism for selective IP traffic offload (SIPTO), considering vehicular communication networks. This mechanism provides support for offload data, seamless transfer, and IP flow mobility to mobile devices equipped with multiple interfaces. The authors created a mechanism called Multilink Striping Management (MSM), which allows the data transfer flow and mobility between different access network technologies. The reports about link quality and the status of the network, such as the network core and access, are used as triggers for the MSM. These triggers support the decision on whether there is a change in the flow, either a data offload or handover, needed to avoid session interruptions. The Media independent handover (MIH) services are used to trigger the need for an change of flow offload data, or handover. Using primitives, MIH, IP flow mobility, handover, and data offload are performed smoothly, allowing better use of network resources while enhancing network capacity.

The authors in [10] developed an architecture, called Seamless Flow Mobility Management Architecture (SFMMA). This architecture consisted of a common infrastructure to seamlessly enable multi-access technology in wireless networks. SFMMA works with WiMax and LTE technologies, as well as technologies for wireless carrier networks, providing a continuous and transparent connection to vehicular applications. The purpose of this architecture is to maximize network traffic while maintaining the minimum requirements of vehicular applications, such as packet loss, throughput, and delay. Thus, a stream manager was created based on application class of vehicle networks and state of each active network in the environment. However, this proposal presents a high number of control messages to establish the return flow between the interfaces. Due to the use of the 802.21 protocol for performing the change of flow, SFMMA architecture uses a significant amount of control messages. For instance, for a change of flow initiated by the Mobile Node (MN), it is required at least 13 control messages, which can leave management slow and possibly unstable mobility.

Observing the limitations of SFMMA, we propose an architecture, which is an evolution of SFMMA, to enhance efficiency in handover decision-making. In this new architecture, we removed the decision-making mechanisms used within MAG and the mobile node in order for Local Mobility Anchor (LMA) to be in charge of all decisions regarding choosing a network. This changes in the architecture are intended to reduce the number of message changes and avoid inconsistencies that existed in SFMMA. In addition to the modification of the message flow trading decision engine, the new architecture proposes a structure in the messages that are changed between the network elements, the LMA, MAG, and NM, in order to further decrease the amount of control messages in network.

III. An Architecture for Flow Mobility Management for Vehicle Networks

In this paper, we propose the development of an architecture called flow mobility MAnagement for VEhicle Networks - MAVEN. This architecture consists of a common infrastructure for enabling seamless multi-access technology in wireless networks and integrating technologies, such as LTE, and wireless technologies for vehicular networks, in order to provide a continuous and transparent connection to vehicular applications. The purpose of this architecture is to maximize the throughput of the network, keeping the minimum requirements of vehicular applications, such as packet loss, throughput, and delay. As a result, we create a flow based manager in the implementing classes of vehicle networks and state of each active network in the environment.

The MAVEN architecture uses the PMIPv6 protocol to address management. In addition, the architecture uses only one decision engine found in LMA in order to decrease the number of unnecessary trade flow between network interfaces [11]. The MAVEN architecture also introduces a new structure of the messages that are changed between the network elements. The structure reduces the amount of network control messages and assists in the decision mechanism of flow change, leaving this function to LMA only and allowing the Mobile Node start the change process.

A. Restructuring 802.21

In order to remove the control messages from the standard 802.21 protocol, a new message called Change_Flow must be introduced in the handover mechanisms with the role of initiating and supporting the management of flow mobility. This message facilitates the change of flow between network interfaces. With this message, we can decrease the amount of control messages in the network, streamlining the process of change of flows, because it carries information relevant to the current change, thereby eliminating approximately 5 messages from the standard 802.21 protocol.

The Change_Flow message contains the following fields: (i) ID_message, which is the message identifier; (ii) ID_Source, which consists of the identifier of who initiated the change (either MN or LMA); (iii) ID_Flowstatus, which identifies the flow; (iv) Home Network Prefix (HNP), which contains the prefixes that need to be modified; (v) MAG, which indicates the MAG currently routing the flow that needs to be modified; and (vi) MN item, which shows the MN that is broadcasting the stream.

Figure 1 illustrates the fields of the message Change_Flow. This message is used when the mobile node requests the change of a certain flow to the LMA. It is noticeable that the MN field is empty since the own mobile node is actually sending the request that has already been identified in the field ID_Source, thus not needing to use the MN field. The message must also indicate the flow prefix to which the MAG is connected. When the message is intended to provide information about any change on the MAG, such as a message that comes out of the LMA to the MAG, the MAG field is the address of the new MAG that is assuming the flow.

ID_MESSAGE	ID_SOURCE	ID_FLOW	HNP	MAG	NULL

Fig. 1. Fields of the Change_Flow message

When the change is established through updates on the tables of PMIPv6 and 802.21, a message is sent in response to this request, as depicted in Figure 2. This message contains the message ID, which identifies the request, and a response field, which indicates the status of the request. If the update of the change was successful, the response is an *OK*; otherwise, the response contains the error that occurred during the process. In the presence of an error, a new request is built. The Get_Inform message and the standard message of the 802.21 protocol are maintained so that the mobile node and the LMA can access to the information about the network and its flows.

ID_MESSAGE	1- OK

Fig. 2. Fields of the Change_flow confirmation message

B. Handover Procedure

Creating a flow occurs when a mobile node initializes an application and starts sending messages in the network. However, the manner in which the flow traverses the network may change over time. For instance, throughout its existence, a stream that is originally set to be sent by a particular network technology may be routed by other technology. This change in flow might be initialized in two different locations: at the mobile node and at the LMA.

The return flow can be initialized by the vehicle. This initialization can occur (i) upon the activation of a network interface or (ii) when the network parameters or the status of current flow do not meet the minimum requirements of the application (flow, packet loss, and delay).

When a new network interface is activated, there are two events to consider: (i) if all applications are mapped to another network interface, and (ii) if there is a previously mapped flow to this interface, and this flow was established in the LMA. Thus, the LMA allocates the same network prefix of the destination stream. Otherwise, the LMA allocates a new network prefix.

If a network parameter is outside the expected limits by showing high packet loss or high delay in a given flow, the node can initiate an change interface, so the flow requirements can be met.

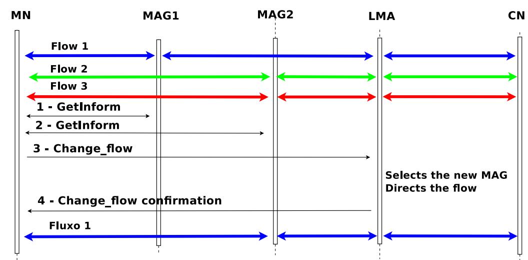


Fig. 3. Sequence Diagram for the interface change initiate in the mobile node

Figure 3 describes the steps involved in the flow change when the procedure is initiated by the mobile node. When the node determines that some of the parameters of the status of the flow or the network parameters are outside the expected values (step 1), it begins the flow change to a new interface. First, the MN sends a message to the LMA (step 2), requesting the flow change. The LMA analyzes the best MAG for that specific mobile node and connects it by changing the flow to the new MAG, informing the vehicle the situation of this change (Step 3). The MN, after receiving this notification, starts sending messages to the flow in the new path.

The process of flow change in LMA is much simpler than in MN because LMA contains an overview of the current state of the network, as well as all the information needed to make a flow change. There are two ways of accomplishing this change: (i) when the LMA is aware of an HNP connected to this stream and (ii) when the MAG does not contain any HNP connected to this flow.

Figure 4 describes the change of the flow made by the LMA. In the first case, the LMA MAG2 is aware of HNP1 being connected to stream 1, so that the LMA conducts the change of the flow directly. In the second case, MAG1 contains an HNP2 connected to the flow 2, and the LMA consequently tells MAG1 that HNP2 is responsible for forwarding the packets flow 2 (1). In the end, the MN is notified and begins to forward packets to the new MAG (2).

To assist in the message change decision, a mechanism is needed for indicating the best interface for a given flow. For this, we used a fuzzy logic-based engine developed by Meneguette et. al. [10].

IV. Evaluation

In order to evaluate the proposed architecture, experimental simulations have been conducted in different scenarios. We

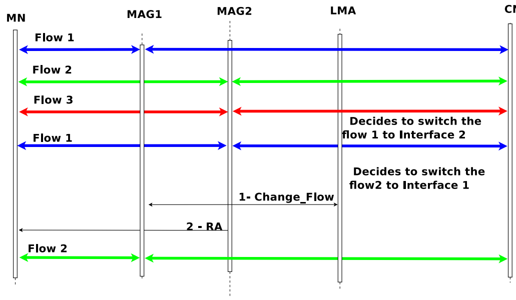


Fig. 4. Sequence diagram employed in the packet change initiated by LMA

then discuss the results of the comparison of the proposed architecture for flow mobility management for vehicle networks (MAVEN) with other architectures in the literature.

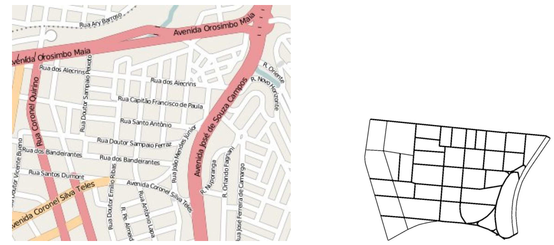
A. Description of the Scenarios

The MAVEN architecture has been implemented in the network simulator simulator (NS 3.13). We used PMIPv6 model that was developed by Hyon-Young Choi [12], as well as the 802.21 model [13]. The aim of the simulations was to assess the impact that our architecture on both the network and applications. We intend to verify that the new structuring of 802.21 does not cause an overload on the network, and the time of flow change does not affect the application and network. We used five metrics to evaluate our architecture: throughput, packet loss, delay, handover time, and amount of control messages.

In our simulation scenario, each vehicle was running one application from safety, comfort, and user classes of application. The frequency of messages for each application follows the standards of the European Telecommunications Standards Institute (ETSI) [14] in which security class application sends a message every 0.1s, the user class of application sends a message every 1s, and the comfort class of application sends a message every 0.5 seconds. The number of vehicles in the simulations ranged from 100 to 500, and all vehicles executed the functions of their intended applications at the same time. All vehicles were within range of a wireless access point, and the access points were spread over the map. However, the access point does not cover all areas in the map.

The map used for the simulation was taken from a neighborhood in the city of Campinas, state of São Paulo, Brazil. We used the Urban Mobility simulator (SUMO) [15] to convert the extracted map from OpenStreetMap [16], as shown in Figure 5(b). Moreover, all vehicles contained two network interfaces, LTE and 802.11p, and addresses have been assigned to both interfaces before simulations are executed. For setting up LTE, the default configuration of NS-3 was used; this provided a coverage area of approximately 5 km to the LTE, covering the entire map. However, in the 802.11p settings, we used a propagation model for two-ray ground and radio transmission range of 200 m. Table I describes the simulation parameters.

For each scenario, 40 executions were performed, allowing us to generate results with calculated confidence intervals of 95%. We compared our architecture with SFMMA [10] and IF-HMIPv6 [17]. We have defined three scenarios to evaluate the proposed mobility management model:



(a) Real OpenStreet map (b) SUMO map

Fig. 5. Simulation maps used for the comparison analyses. (Campinas, Sao Paulo, Brazil)

TABLE I. SIMULATION PARAMETERS

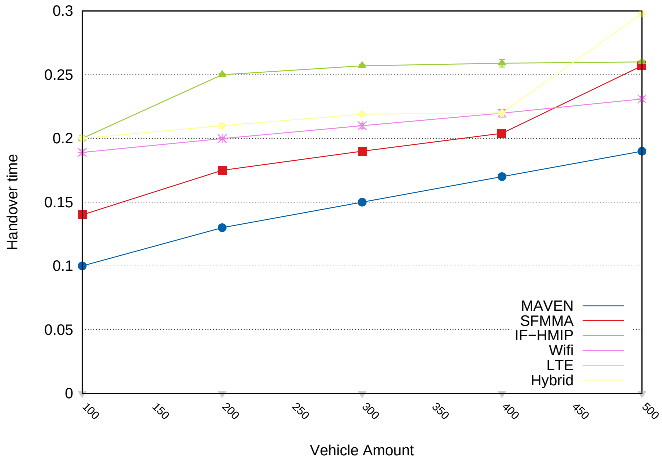
Parameters	values
Power Transmission	1.6 mW
Transmission range	200 m
Number of vehicles	100, 200, 300, 400, 500 vehicles/hour
Frequency safety class	0.1s
Frequency user class	1s
Frequency comfort class	0.5s

- LTE: only LTE network is used to transmit and receive information.
- WiFi: only WiFi network is used to transmit and receive information.
- Hybrid: Both networks, LTE and WiFi, are active in the environment, but we only send information about the single interface to which the node is connected. To change a network node interface, a threshold mechanism is used, considering the signal strength for the execution of handover. All nodes are initially connected to the WiFi network.

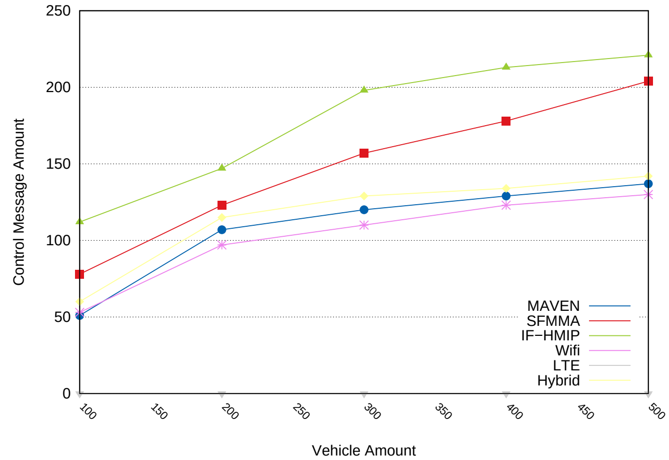
B. Experimental Results

Figure 6(a) shows the mean handover time. In these graphs, it can be seen that the MAVEN has a shorter handover. This result is related to the number of handover occurred, and the network state at the time of handover, besides being related to the amount of control messages on the network. Analyzing the graph, the MAVEN protocol was reduced by approximately 44% compared to the SFMMA and a 60% compared with IF-HMIP. This reduction is due to prior knowledge about network conditions and their flows, avoiding unnecessary changes and to reduce the number of control messages in the network, as we can see in Figure 6(b).

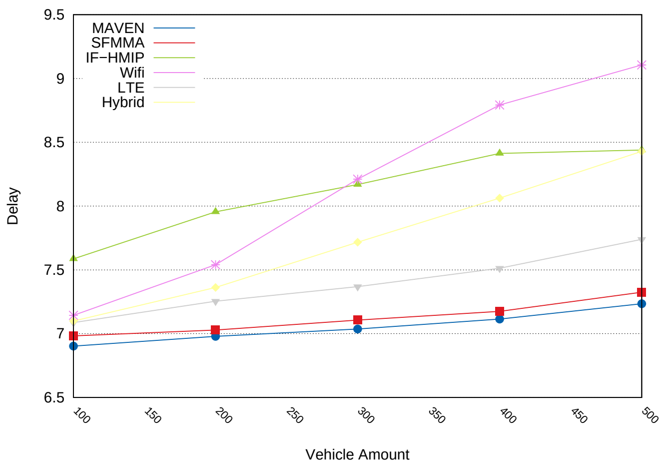
Figure 6(b) shows the amount of control messages generated on the network to carry out the handover. We can see that the proposed solution is close to the scenario that only contains WiFi, in which control messages only match the vehicle's connection to the access point. Therefore, the proposed protocol generates a small number of messages due to the use of the message Change_Flow replacing some standard messaging protocol 802.21. The MAVEN protocol also offered



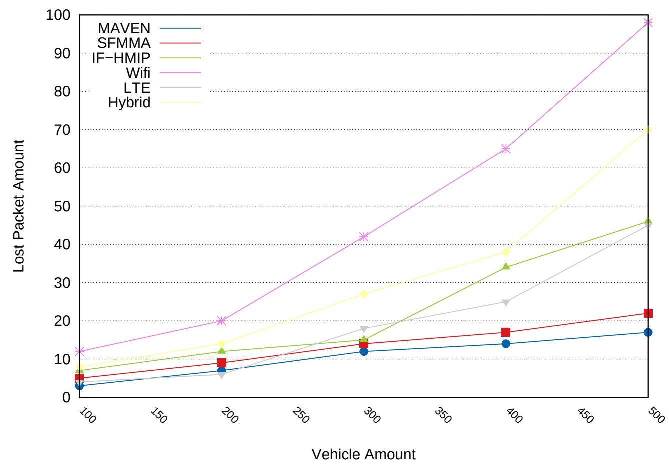
(a) Handover time



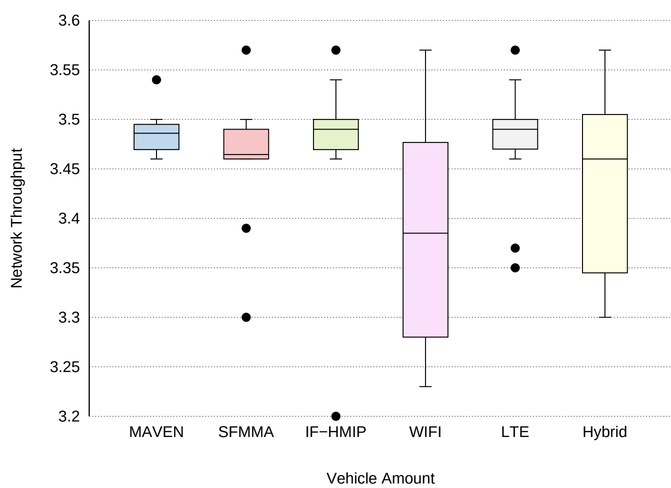
(b) Control Message Amount



(c) Delay



(d) Packet Loss



(e) Throughput

Fig. 6. Results obtained through simulation to make the comparison between our proposal scenarios with other papers and taking into consideration (a) Handover time, (b) control message, (c) delay, (d) packet loss, (e) Throughput,

a reduction in the number of messages of approximately 5% when compared to the Hybrid and a reduction about 50% compared to the IF-HMIPv6. The LTE kept at 0 since it contains only a single antenna, not realizing any return flow. The number of control messages and handover time exercise an impact on message delay, packet loss, and hence in the network flow.

Figure 6(c) shows the average delay of all application classes. It can be observed that MAVEN presents an average reduction in delay of approximately 33% compared to the WiFi and 23% compared to the hybrid. When there are 500 cars in the simulation, the MAVEN reduced by 2% in average delay compared to SFMMA and 10% compared to the mechanism that has only LTE. This is because MAVEN achieves an enhanced balance of packets that are sent between network interfaces, thus not overloading any technology.

It is noticeable in Figure 6(d) that MAVEN achieved less packet loss for all scenarios. Thus, splitting traffic between multiple interfaces avoids the overhead of packet schedulers in each network interfaces on the device. MAVEN protocol provided a division between the interfaces decreasing this package dispute and allowing a low handover time. Providing a reduction of 5% packet loss compared to SFMMA and about 80% compared to the WiFi. This small number of packages impacted on the result of the network flow, as discussed below.

Figure 6(e) shows the flow of the network in a scenario with 500 vehicles. MAVEN protocol obtained less variations in its flow, thus showing an architectural stability to handle a significant quantity of vehicles. Unlike SFMMA, which shows widely scattered points, the proposed solution seems to be more concise. Looking at the IF-MIPv6 protocols, LTE, WiFi, and Hybrid, they present the same change in the behavior of their values due to their unstable architectures.

To summarize, the proposed solution offers a stable architecture that maintains its behavior even in high quantity of data, with low packet loss and an average low delay. This resulted in a reasonable number of incoming messages that allowed a better throughput. This was possible because MAVEN protocol decreased the amount of control messages in the network and decreased the time of handover since the network had relevant information on the conditions of flows that it conveys. The decision on flow change was centralized in LMA, and we used only a message to perform the flow change.

V. Conclusion

In this study we explored the use of more than one network technology to maximize the QoS for applications in vehicular networks. The proposed architecture for flow mobility management deals with different network interfaces at the same time, seeking to maximize network performance, to decrease the delivery time, and to satisfy the minimum packet loss and latency for each class of applications in a vehicular network. As a result of this work, it was observed that the proposed architecture presented a low message delivery time, with lower packet loss, and lower delay. For future work we intend to improve the decision and selection methods near the MAGs for the purpose of further minimize the amount of control messages on the network.

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